10/505140

L1: Entry 2 of 2 File: USPT Oct 31, 2000

DOCUMENT-IDENTIFIER: US 6141606 A
TITLE: Wheel speed control system for spacecraft with rejection of null space wheel momentum

Abstract Text (1):
A spacecraft attitude control system uses at least four reaction wheels In order to minimize reaction wheel speed and therefore power, a wheel speed control means system is provided. The wheel speed control means monitors the wheel speeds and controls wheel speed nullspace components to keep the wheel speeds as small as possible.

Brief Summary Text (6):
Spacecraft attitude stabilization may be accomplished by spinning the spacecraft and by mounting the sensors or antennas on a stabilized despun platform. Alternatively, the spacecraft may be stabilized in three axes. Three-axis stabilization may be accomplished by a control system using fuel-burning thrusters, but the use of such thrusters requires the expenditure of fuel, which tends to limit the service life of the spacecraft. Another method for three- axis stabilization uses magnetic coils or torquers which interact with the magnetic fields of the heavenly body being orbited to provide the desired torques. Magnetic torquers have the disadvantages that the available torques tend to be small, and undesirably dependent upon the local magnitude of the magnetic field of the particular heavenly body being orbited. The magnetic fields change from time to time and from location to location. The salient advantage of magnetic torquers, however, is that their operation requires only electrical energy, which may be a renewable resource on spacecraft equipped with solar panels.

Brief Summary Text (15):
The present invention is distinct from the system disclosed in the Goodzeit et al. patent in that it does not require generating a wheel speed error vector because the present invention controls wheel speed nullspace components instead of wheel speed errors.

Brief Summary Text (16):
Furthermore, the present invention has the flexibility to control the nullspace components to non-zero values, which is a capability not possible with the system disclosed in the Goodzeit et al. patent.

Brief Summary Text (19):
Another object of the present invention is to provide a wheel speed control system that controls wheel speed nullspace components.

Brief Summary Text (20):
Still another object of the present invention is to provide a wheel speed control system that reduces wheel speed nullspace components to desired values which are often zero.

Detailed Description Text (5):

where D is an 3.times.N matrix. When N>3, D has more columns than rows and one can construct M.DELTA.N-3 column matrices column matrices V.sub.1, . . . M which form an orthonormal basis for the row nullspace of D (that is DV.sub.i =0, and V.sub.i =1, and V.sub.j =0 for i.noteq.j)

Detailed Description Text (6):
A property of the nullspace vectors V.sub.1, . . . , V.sub.M is that adding them to the wheel speeds does not affect the overall momentum of the spacecraft. Thus when C.sub.1, . . . , C.sub.M are any scalars, the wheel speeds ##EQU2## correspond to the same total momentum as ##EQU3##

Detailed Description Text (11):
The relationship between these variables can be written as ##EQU5## where D is the same 3.times.N matrix as in equation (1). When there are exactly three momentum wheels, only one set of values for T.sub.1,T.sub.2,T.sub.3 can produce any set of T.sub.x,T.sub.y,T.sub.z values, However when there are more than three wheels, many sets of T.sub.1, . . . ,T.sub.N values exist which produce any particular set of T.sub.x,T.sub.y,T.sub.z values. Just as adding the nullspace matrices V.sub.1, . . . , V.sub.M to the wheel speeds does not affect the total momentum, adding V.sub.1, . . . , V.sub.M to the torque scalars does not affect the total torque on B. Thus when C.sub.1, . . . , C.sub.M are any scalars, the values of T.sub.x,T.sub.y,T.sub.z corresponding to ##EQU6## are the same as those corresponding to ##EQU7##

Detailed Description Text (13):
The present invention keeps the wheel speeds as small as possible by driving the nullspace components to zero. An embodiment of a system for providing wheel torques according to the present invention is illustrated by the block diagram of FIG. 1 and by the more detailed block diagram of elements 12, 14 and 16 in FIG. 3. In FIG. 1, for a spacecraft having N momentum wheels with axes w.sub.1 . . . w.sub.n . . . , the control torque signals which are torque commands Tx, Ty and Tz obtained from the spacecraft attitude sensors are applied to processor 10 that generates matrix signals and provides an output signal T representative of nominal wheel torques.

Detailed Description Text (14):
Current wheel speeds .omega..sub.1, .omega..sub.2, .omega..sub.3, . . . , .omega..sub.n of the spacecraft momentum wheels are applied to processor 12 that carries out a matrix multiplication to provide an output signal z which is the scalar nullspace value of the wheel speeds. The z signal is applied to integrator means 14 that generates the integral signal I then matrix multiplication means 16 provides .DELTA.T signals that are applied to the nominal wheel torque signals from processor 10 to provide desired wheel torque signals on output lead 18.

Detailed Description Text (17):
Next form the columns matrices V.sub.1, . . . ,V.sub.M such that they form an orthonormal basis for the row nullspace of D, where M.DELTA.N-3.

Detailed Description Text (18):
Then define the scalars z.sub.1, . . . ,z.sub.M as the scalar projection of w.sub.1, . . . ,w.sub.N in the nullspace of D ##EQU9##

Detailed Description Text (24):
Both the present invention and the cited Goodzeit et al. patent U.S. Pat. No. 5,058,835 start by calculating a set of nominal control torques T.sub.1, . . . , T.sub.N and then determine values for .DELTA.T.sub.1, . . . , .DELTA.T.sub.N which, when added to the nominal control torques, cause the wheels to go towards their optimal speeds. However, the manner in which the two inventions determine values for .DELTA.T.sub.1, . . . , .DELTA.T.sub.N are fundamentally different. U.S. Pat. No. 5,058,835 requires forming a wheel speed error matrix e.sub.1, . . . , e.sub.N which represents the difference between the current wheel speeds and the optimal

wheel speed and the optimal wheel speeds. The disclosed invention however, instead of controlling the wheel speed error, controls the nullspace components of the wheel speeds. This saves data storage and many calculations by avoiding the costly and unnecessary step of forming a wheel speed error matrix.

Detailed Description Text (26):
Thus, it is seen that the system of U.S. Pat. No. 5,058,835 is significantly less efficient because it controls the wheel speed errors, while the disclosed present invention controls the nullspace components of the wheel speeds.

Detailed Description Text (31):
However, referring to FIG. 3, in the disclosed present invention the first step is to determine the current wheel speeds .omega..sub.1, .omega..sub.2, .omega..sub.3, .omega..sub.4, and calculate the nullspace scalar projection z.sub.1. ##EQU14## where z.sub.1 is a scalar and V.sub.1 is a column matrix.

Detailed Description Text (34):
Use of equations (19) and (20) drives the nullspace wheel momentum to zero. Although nullspace wheel momentum is undesirable in general, there are some situations where it is desirable to control the nullspace wheel momentum to a specified non-zero value. Replacing "z.sub.1 " with (z.sub.1 -z.sub.1)" in equation (19) and (20) causes the nullspace wheel momentum to be controlled to z.sub.1.

Detailed Description Text (37):
What has been described is an improved wheel speed control system for spacecraft momentum wheels that controls wheel speed nullspace components to reduce wheel speed nullspace components to zero.

CLAIMS:

1. In a body containing supernumerary active angular momentum storage devices, a processing means comprising means for determining a set of actuator torques to cause said storage devices to exert the desired control torque on said body, and means for causing the nullspace components of the angular speeds of said storage devices to move towards specified values.

3. A control system for a spacecraft, comprising:

N.gtoreq.4 active reaction wheels configured to provide three-dimensional angular momentum storage, said reaction wheels adapted to receive torque drive signals for torquing said spacecraft under the control of said torque drive signals,

sensing means for determining or estimating wheel speed signals .omega..sub.1, . . . ,.omega..sub.N,

attitude control means coupled to said sensing means for generating torque control signals T.sub.x,T.sub.y,T.sub.z,

a first computational means responsive to said torque signals T.sub.x,T.sub.y,T.sub.z to provide output signals T.sub.1. . . ,T.sub.N, representative of nominal wheel torques,

a second computational means responsive to said wheel speed signals .omega..sub.1, . . . ,.omega..sub.N to provide M.DELTA.N-3 output signals z.sub.1, . . . ,z.sub.M which are scalar nullspace values of said wheel speeds,

a third computational means responsive to said output signals z.sub.1, . . . ,z.sub.M for generating delta torque signals .DELTA.T.sub.1, . . . ,.DELTA.T.sub.N, and

means for combining said delta torque signals and said nominal wheel torque signals to produce wheel torque signals which provide the desired wheel torques which provide the desired control torques T.sub.x,T.sub.y,T.sub.z while keeping speeds small by controlling said output signals z.sub.1, . . . ,z.sub.M to desired values.

6. A control system for a spacecraft, comprising:

N.gtoreq.3 active reaction wheels configured to provide two-dimensional angular momentum storage, said reaction wheels adapted to receive torque drive signals for torquing said spacecraft under the control to said torque drive signals,

sensing means for determining or estimating wheel speed signals .omega..sub.1, ...omega..sub.N,

attitude control means coupled to said sensing means for generating torque signals T.sub.x,T.sub.y,

a first computational means responsive to said torque signals T.sub.x,T.sub.y to provide output signals T.sub.1, . . . ,T.sub.N, representative of nominal wheel torques,

a second computational means responsive to said wheel speed signals .omega..sub.1, . . . ,.omega..sub.N to provide M.DELTA.N-2 output signals z.sub.1, . . . ,z.sub.M which are scalar nullspace values of said wheel speeds,

a third computational means responsive to said output signals z.sub.1, . .

. ,z.sub.M for generating delta torque signals .DELTA.T.sub.1, ...DELTA.T.sub.N, and

means for combining said delta torque signals and said nominal wheel torques to provide wheel torque signals which provide the desired control torques T.sub.x,T.sub.y while keeping speeds small by controlling said output signals z.sub.1, . . . ,z.sub.M to desired values.

9. A control system for a spacecraft, comprising:

N.gtoreq.2 active reaction wheels, configured to provide one-dimensional angular momentum storage, said reaction wheels adapted to receive torque drive signals, for torquing said spacecraft under control of said torque drive signals,

sensing means for determining or estimating wheel speed signals .omega..sub.1, . . . ,.omega..sub.N

attitude control means coupled to said sensing means for generating torque control signal T.sub.x,

a first computational means responsive to said torque signal T.sub.x to provide output signals T.sub.1, . . . T.sub.N, representative of nominal wheel torques,

a second computational means responsive to said wheel speed signals .omega..sub.1, . . . ,.omega..sub.N to provide M.DELTA.N-1 output signals z.sub.1, . . . ,z.sub.M which are scalar nullspace values of said wheel speeds,

a third computational means responsive to said output signals z.sub.1, . . . ,z.sub.M for generating delta torque signals .DELTA.T.sub.1, . . . ,.DELTA.T.sub.N, and

means for combining said delta torque signals and said nominal wheel torque signals

to produce the wheel torque signals which provide the desired wheel torques which provide the desired control torque T.sub.x while keeping speeds small by controlling said output signals z.sub.1, . . . ,z.sub.M to desired values.

12. A control system for a spacecraft, comprising:

attitude control sensing means for generating attitude signals representative of spacecraft 3-axis x, y, z, attitude having N reaction wheels rotating at wheel speeds .omega..sub.1, .omega..sub.2, .omega..sub.3, ...omega..sub.N and adapted to receive torque drive signals for torquing said spacecraft under the control of said torque drive signals;

attitude control means coupled to said attitude control sensing means for processing at least said attitude signals for generating torque control signals T.sub.x, T.sub.y, T.sub.z ;

a control means connected to said attitude control means and responsive to said torque control signals and connected to said reaction wheels and responsive to wheel speed signals, said control means including a matrix signal generator means responsive to said torque signals Tx, Ty, Tz to provide output signals T.sub.1, . . . ,T.sub.N representative of nominal wheel torques, a first computational means responsive to said wheel speed signals to provide output signals z.sub.1, . . . ,z.sub.M which are scalar nullspace values of said wheel speeds, a second computational means responsive to said output signals z.sub.1, . . . ,z.sub.M for generating delta torque signals .DELTA.T.sub.1, . . . , .DELTA.T.sub.N, and means for combining said .DELTA.T.sub.1, . . . , .DELTA.T.sub.N, signals and said nominal wheel torque signals T.sub.1, . . . , T.sub.N to produce wheel torque signals which provide the desired control torques T.sub.x, T.sub.y,T.sub.z while keeping wheel speeds small by controlling said z.sub.1, . . . ,z.sub.M signals to a desired value.

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Freeform Search

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L8	L7 not l1	7	L8
L7	L6 and 701/13.ccls.	7	L7
L6	L5 and @ad<=20020220	326	L6
L5	((balanc$ or equ$) same thrust$) and (nullspace$ or null$)	1163	L5
L4	L3 and l1	1	L4
L3	((balanc$ or equ$) with thrust$) and nullspace$	1	L3
L2	(balanc$ with thrust$) and nullspace$	0	L2
L1	thrust$ and nullspace$	2	L1

END OF SEARCH HISTORY

10/505140

L22: Entry 1 of 1 File: USPT Sep 7, 2004

3

DOCUMENT-IDENTIFIER: US 6786896 B1
TITLE: Robotic apparatus

Application Filing Date (1):
20000717

Brief Summary Text (16):
However, the mass and configuration of the effector affects the dynamics and kinematics of the entire system. In typical cases, the effector is counter balanced by other elements of the system. Thus, to the extent that effectors are interchangeable, this interchangeability feature should be accomplished without rendering the remainder of the system overly complicated.

Detailed Description Text (189):
The null-space vector q.sub.null 516 (the combination of joint moves that does not cause any tip translation) of the slave at the current joint configuration may be computed during the SVD routine mentioned above.

Detailed Description Text (190):
Scaling and adding 520 the null-space vector to the desired velocity provides control of the slave arm within the redundant DOF. The magnitude value a determines the speed of motion inside this null space and is selected to minimize a cost function C(q). It is also limited 518 to prevent undesirably fast motions. ##EQU6##

Detailed Description Text (243):
The wrist unit would perform some tasks better if it were, in general, stronger than described above. The full actuator potential of the base can not be used with the wrist described, partially because it is undesirable to pretension the wrist more, due to the limited strength of the wrist unit and the Spectra.TM. plastic cable used. More pretension would require stainless steel, or better yet, tungsten wrist cable. Metal cable however, tends to preclude a non-alpha wrist design, due to the extra friction created by alpha wraps when used with metallic cable. That would lead, then, to a bulkier wrist. It is critical that friction in the wrist be reduced if macro-micro type controllers are to be used for implementing force reflection. Thus, the designer must balance these considerations depending on the desired application.

Detailed Description Text (246):
A master wrist with more DOFs may also be desirable. While using the system, one often runs into rotational limits of the master well before running into such limits on the slave. One solution is to use a kinematically identical master and slave, so that singularities and joint limits are aligned. However reorientation of the slave relative to the patient would then require reorientation of the master to keep this benefit. Another solution is to increase the range of motion of the master wrist, (i.e., the portion kinematically more distant from ground than the link 1.sub.M 2) most likely through the use of a four DOF wrist, that is through the addition of an output roll. In order to take advantage of this however, the

master gimbal must have at least one computer controlled, powered joint (most likely the input roll (closest to ground)) in order to ensure that singularities are avoided. There is another reason to power the master wrist joints when the device is used for MIS. When the surgeon lets go of the master (which happens frequently), the master wrist will simply fall. Even if it were balanced, one could bump it easily. The slave wrist will then track this motion, potentially causing damage to tissue. Assuming that sensors are incorporated to determine whether or not the surgeon is holding the master, then there are two options. First the master and slave can be disconnected in software, so that when the master wrist falls, the slave wrist does not move. In this case, reengaging the system may present a problem. The surgeon would have to realign the two (with some sort of visual cues displayed on the video monitors for example) before the controller would re-engage the system. The second option is that the master gimbal is powered so that when the surgeon lets go, it simply freezes in position so that misalignment between the master and slave never occurs. Another advantage of this approach is that if the slave manipulator is manually repositioned with respect to the patient, the master manipulator can reposition and reorient itself automatically in order to maintain visual correspondence between the two.

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L11: Entry 1 of 7 File: USPT Jan 12, 1999

DOCUMENT-IDENTIFIER: US 5857623 A
TITLE: Device and method to provide stabilized delivery of pressurized liquid

Abstract Text (1):
A nozzle body and coupler bearing assembly for discharging a liquid material. The nozzle body consists of approximately thirty-two serially and concentrically arranged ports which receives liquid from an attached hose under high pressures. The various points of placement of the ports, combined with the rotation produce a balanced and stabilized effect on the rotating nozzle assembly which allows the nozzle assembly to be delivered to a target area, and while in operation, have the ability to be left unattended by fire-fighting personnel. The wild and natural whipping action exhibited from a fire hose under high operating pressures is nullified with the present nozzle. The body of the nozzle is a hollow paraboloid attached to a coupler bearing assembly. The nozzle body is made from a resilient and durable material with concavo-convex surfaces with a plurality of ports emitting liquid in a radial "Dandelion puff" pattern. Three of the four port groups have approximate angles which are arranged tangentially and acutely to the axis of rotation and flow. The fourth group has an approximate angle which is arranged acutely to the horizontal plane of the longitudinal axis of rotation and flow. The nozzle assembly may be transported, delivered, placed, propelled, launched, carried, or otherwise put in any mode, means, or fashion to a target to which a liquid needs to be provided or dispersed.

Application Filing Date (1):
19960904

Detailed Description Text (4):
FIG. 1b depicts one of a number of rearward thrust-stabilizing ports 155, positioned radially and concentrically about the nozzle body 100. These are positioned at an approximate acute angle 195 to the horizontal plane 160 which passes though the longitudinal axis 110. As fluid enters the nozzle body 100 it is emitted through the rearward thrust-stabilizing ports 155. The rearward thrust-stabilizing ports 155 emit a spray of liquid with a radial direction generally depicted in the drawings by the number 180; wherein said liquid produces a thrust-stabilizing force depicted as the vector space cone 175; wherein said thrust-stabilizing force 175 cancels the net translational gyroscopic force produced by the forward gyroscopic ports 140. Precession is the natural tendency of the gyroscopic influences, however, since the rearward force 175 originates from an offset position 185 on the horizontal plane 160 to the axis 110, the precessional tendency is nullified. Thus, considering at this point all of the right-angle influences, tangential forces, moments of inertia, and gyroscopic forces of a free-rotating solid body; the net force translated is zero producing a torque-free rotation. The acute approximate angle 195 of the rearward ports 155 also produces a thrust force 175 in a direction generally indicated by the number 180. FIG. 2a depicts a front (top) view of the nozzle body. The ports 140, 145, 150, and 155 are generally positioned in sets, in a concentric pattern about the center axis that is 110 in FIGS. 1a and 1b, forming a plurality of ports as shown in FIG. 2a. A horizontal axis 160 and vertical axis 170 are shown to give proper reference and orientation. The ports 140, 145, 150, and 155 are offset successively from each other at smaller approximate acute angles 196. Dotted line cylinders are used for

one member of each set of ports to depict the approximate angular orientation of each set of ports.

Detailed Description Text (7):
Once the entire nozzle assembly 410 has been delivered to a target 520, the liquid is released in the spray pattern as described and, as described earlier, the various vector forces are nullified, thereby allowing free nozzle body rotation and requiring no personnel in controlling attendance. This feature relieves the operator from having to be in proximity to a hazardous area thus solving two of the problems of prior art nozzles. This solves the earlier described problem of having to have one or more operating and controlling personnel in attendance to operate and control a prior art nozzle attached to a hose under high pressures because the prior art nozzle thus attached will whip about wildly and itself become a lethal object. It also solves the earlier described problem of a prior art nozzle thus attached to a hose under high pressures whereby the nozzle and hose whip about wildly and uncontrolled. The nozzle of the present invention eliminates the natural whipping tendency and stabilizes the nozzle as attached to the hose under high liquid pressures. The paraboloid body, with its pointed end, being made a projectile and being attached to a hose under high pressures and being launched at an intended target has the ability to penetrate a barrier unassisted by an operator once launched thus solving another problem of prior art nozzles. While the above description pertains to the preferred embodiment of the invention, numerous variations, changes and substitutions may occur to those of ordinary skill in the art without novel or non-obvious departure from what is claimed herein. For example, realignment on the nozzle body 100 of port placement, orientation, position, etc., which preserve the cancellation of vector forces would be constituted as obvious enhancements. So too, would be changes and variations in the material used to construct the nozzle, or in its shape, so long as the basic cancellation of forces and ability to launch to a target area is preserved. The coupler bearing assembly 355 disclosed herein is one of a limitless variety of such assemblies that can be conceived by a person of ordinary skill in the art to permit attachment of the nozzle body 100 to a hose 400 while allowing it to freely rotate about the axis of rotation 110 described herein, and any of these variations is squarely contemplated and foreseen within the present disclosure.

CLAIMS:

6. The apparatus of claim 1, wherein:

said thrust-inducing nozzle port means are positioned upon the nozzle body nearest a forward region of said nozzle body and are substantially-equally spaced along at least one forward circumferential curve concentric to said axis of rotation; are oriented at an acute angle of approximately 30 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at an angle of approximately zero degrees with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, thereby opposing and substantially cancelling said gyroscopic precession; wherein

said rotation-inducing and centripetally-stabilizing nozzle port means are positioned approximately upon a middle region of the nozzle body and are substantially-equally spaced along at least one middle circumferential curve concentric to said axis of rotation; are oriented at an angle of approximately 90 degrees through said nozzle body relative to the orientation of said axis of rotation thereby not substantially contributing a net thrust along said axis of rotation; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, causing said nozzle to rotate about the axis of

rotation while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of said ports along said at least one middle circumferential curve; wherein

said thrust-cancelling nozzle port means are positioned upon the nozzle body nearest a rear region of said nozzle body and are substantially-equally spaced along at least one rear circumferential curve concentric to said axis of rotation; are oriented at an obtuse angle of approximately 150 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said forward thrusting force to substantial cancel said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, further causing said nozzle to rotate in the same direction as is caused by the middle-positioned ports, while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of the rearward-located ports along said at least one rear circumferential curve.

12. The nozzle body of claim 7, wherein:

said thrust-inducing nozzle port means are positioned upon the nozzle body nearest a forward region of said nozzle body and are substantially-equally spaced along at least one forward circumferential curve concentric to said axis of rotation; are oriented at an acute angle of approximately 30 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at an angle of approximately zero degrees with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, thereby opposing and substantially cancelling said gyroscopic precession; wherein

said rotation-inducing and centripetally-stabilizing nozzle port means are positioned approximately upon a middle region of the nozzle body and are substantially-equally spaced along at least one middle circumferential curve concentric to said axis of rotation; are oriented at an angle of approximately 90 degrees through said nozzle body relative to the orientation of said axis of rotation thereby not substantially contributing a net thrust along said axis of rotation; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, causing said nozzle to rotate about the axis of rotation while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of said ports along said at least one middle circumferential curve; wherein

said thrust-cancelling nozzle port means are positioned upon the nozzle body nearest a rear region of said nozzle body and are substantially-equally spaced along at least one rear circumferential curve concentric to said axis of rotation; are oriented at an obtuse angle of approximately 150 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said forward thrusting force to substantial cancel said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, further causing said nozzle to rotate in the same direction as is caused by the middle-positioned ports, while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of the rearward-located ports alone said at least one rear circumferential curve.

18. The method of claim 13, wherein:

said thrust-inducing nozzle port means are positioned upon the nozzle body nearest a forward region of said nozzle body and are substantially-equally spaced along at least one forward circumferential curve concentric to said axis of rotation; are oriented at an acute angle of approximately 30 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at an angle of approximately zero degrees with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, thereby opposing and substantially cancelling said gyroscopic precession; wherein

said rotation-inducing and centripetally-stabilizing nozzle port means are positioned approximately upon a middle region of the nozzle body and are substantially-equally spaced along at least one middle circumferential curve concentric to said axis of rotation; are oriented at an angle of approximately 90 degrees through said nozzle body relative to the orientation of said axis of rotation thereby not substantially contributing a net thrust along said axis of rotation; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, causing said nozzle to rotate about the axis of rotation while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of said ports along said at least one middle circumferential curve; wherein

said thrust-cancelling nozzle port means are positioned upon the nozzle body nearest a rear region of said nozzle body and are substantially-equally spaced along at least one rear circumferential curve concentric to said axis of rotation; are oriented at an obtuse angle of approximately 150 degrees through said nozzle body relative to the orientation of said axis of rotation, thereby causing said forward thrusting force to substantial cancel said rearward thrusting force; and when projected onto a plane of rotation normal to the axis of rotation, are further oriented at a substantially non-normal angle with respect to geometric radii originating at the axis of rotation and extending radially-outward through said plane of rotation, further causing said nozzle to rotate in the same direction as is caused by the middle-positioned ports, while causing said centrifugal forces to be substantially cancelled by virtue of the substantially-equal spacing of the rearward-located ports along said at least one rear circumferential curve.

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L15: Entry 4 of 4 File: USPT Dec 10, 1974

DOCUMENT-IDENTIFIER: US 3854138 A
TITLE: RADIOLOCATION SYSTEM PARTICULARLY ADAPTED FOR AIRCRAFT LANDING SYSTEMS

Application Filing Date (1):
19730517

Detailed Description Text (16):
If a vector sum V were thus determined for each azimuth .delta. by vector addition, the absolute values of the vector sums for all angles .delta., plotted against .delta., would yield a curve which is referred to here as a "virtual pattern." The term "virtual" expresses the fact that this pattern does not really exist in space. It is, however, identical to the real group pattern of FIG. 4, which is obtained if the radiators 1.9 and 1.10 of the linear antenna array of FIG. 1 were fed simultaneously and with equal magnitude and equal phase.

CLAIMS:

1. A radiolocation system particularly adapted for aircraft guidance in a terminal area and providing an ILS type presentation of air-derived angular guidance information based on group beacon transmissions, which includes a linear array of N substantially identical and substantially equally spaced radiators sequentially and cyclically energized from a transmitter producing signals of substantially constant phase and amplitude, said ground beacon also being arranged to transmit a pulse train prior to each ground beacon radiation cycle, said ground beacon transmitting a reference signal to facilitate remote phase measurements, comprising:

a receiver located on said aircraft, said receiver including means responsive to said pulse train for determining the beginning of a ground beacon commutation cycle;

means within said receiver for comparing the amplitude and phase of said reference signal with the amplitude and phase of energy received from each radiator of said ground beacon array energized, to produce a plurality of measured amplitude and phase values;

means for adding said measured values vectorially to form a first vector sum;

means for determining the absolute value of said first sum to produce a value representative of the field strength which a group antenna pattern with a single main lobe would produce along a directional line perpendicular to said linear array at the location of said receiver;

means for shifting one half of the measured values by 180.degree. in phase;

means responsive to said phase shifted measured values and the balance of said measured values in unmodified form for deriving a second vector sum, and for producing the absolute value thereof, said second vector sum absolute value characterizing a double-lobe group pattern with null on said directional line

perpendicular to said linear array;

and means for taking the quotient of said first and said second vector sum absolute values for producing a signal having the same variational characteristics about said directional line perpendicular to said linear array as is produced by an ILS system.

Previous Doc Next Doc Go to Doc#

L19: Entry 1 of 2 File: USPT Aug 9, 1994

DOCUMENT-IDENTIFIER: US 5336982 A
TITLE: Dual-arm generalized compliant motion with shared control

Application Filing Date (1):
19930324

Brief Summary Text (19):
[9.] K. Kreutz and A. Lokshin, "Load balancing and closed-chain multiple arm control," Proceedings American Control Conference, pages 2148-2154, Atlanta, Ga., June 1988.

Detailed Description Text (95):
The components of the force vector .function..sub.12 which are in the nullspace of A.sup.T comprise the squeeze forces [4], .function..sub.12s, and the components of .function..sub.12 which are in the vector space of A.sup.T comprise the move forces, .function..sub.12m, i.e.,

Other Reference Publication (8):
K. Kreutz and A. Lokshin, "Load balancing and closed-chain multiple arm control," Proceedings American Control Conference, pp. 2148-2154, Atlanta, Ga., Jun. 1988.

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Search Results - Record(s) 1 through 2 of 2 returned.

☐ 1. Document ID: US 6330483 B1

Using default format because multiple data bases are involved.

L1: Entry 1 of 2 File: USPT Dec 11, 2001

US-PAT-NO: 6330483
DOCUMENT-IDENTIFIER: US 6330483 B1

TITLE: Optimal control system

DATE-ISSUED: December 11, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Dailey; Russell L.	Newcastle	WA		

US-CL-CURRENT: 700/28; 318/561, 318/606, 700/31, 700/44, 700/45, 700/89

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

☐ 2. Document ID: US 6141606 A

L1: Entry 2 of 2 File: USPT Oct 31, 2000

US-PAT-NO: 6141606
DOCUMENT-IDENTIFIER: US 6141606 A

TITLE: Wheel speed control system for spacecraft with rejection of null space wheel momentum

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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Terms	Documents
thrust$ and nullspace$	2

L1: Entry 1 of 2 File: USPT Dec 11, 2001

DOCUMENT-IDENTIFIER: US 6330483 B1
TITLE: Optimal control system

Detailed Description Text (99):
The present invention can address absolute value constraints. One type of nonlinear constraint requires special treatment. If a sum of absolute value terms needs to observe an equality or inequality constraint, a straightforward linear matrix representation of the problem cannot account for this directly, because the derivative of an absolute value term is discontinuous at zero. An example is a limit on nozzle area or total thrust for bidirectional thrusters: the thruster setting can be negative or positive (to represent left or right thrust, for example) but the magnitude of the thrust must be constrained. There is a relatively simple way to handle this in an L1 output mixer. Assume the need to use the absolute value of a variable x, either alone or in another equation. Then define a new unknown variable x.sub.a to be solved for in the u vector, to contain the absolute value of x. Define two inequality constraints, having strong W.sub.n penalty weights, to enforce these relationships: x.sub.a +x.gtoreq.0 and x.sub.a -x.gtoreq.0. Then the L1 Solver will force x.sub.a to equal the absolute value .vertline.x.vertline. in order to eliminate these inequality penalties.

Detailed Description Text (107):
FIG. 18 illustrates the results of implementing an L1 Optimizer for output mixing in the missile fin example of FIG. 15. Starting with the same F matrix used before to define roll, pitch, and yaw in terms of fin deflection, the first step is to add an additional row defining a constraint equation on the four fin deflections that is normally desired to be zero, and which corresponds to "wasted" fin motion producing no net change in pitch, roll, or yaw. Such constraint equations can be found easily by applying the singular value decomposition (SVD) to the F matrix, to identify the nullspace of the matrix. Since this target quantity is orthogonal to the motions producing roll, pitch, and yaw, the constraint signal is given the name "ortho." The motion corresponds to feathering adjacent pairs of fins toward each other so that their forces, except for drag, cancel out.

Detailed Description Text (116):
Examples of control effectors include aircraft or missile control surfaces, thruster nozzle areas, hydraulic servo valves, electric motors and servos, engine controls, and others. Nearly all practical control effectors have upper and lower bounds, such as bounds on control surface deflection angle, and also have slewing rate limits. One example of additional equality constraints that the L1 output mixer can handle is an area matching constraint, in which the sum of several thruster nozzle areas must be held constant. An example of an inequality constraint in a hydraulic system, would be keeping the sum of all servo valve flow rates below a set maximum.

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Search Results - Record(s) 1 through 7 of 7 returned.

☐ 1. Document ID: US 6463365 B1

Using default format because multiple data bases are involved.

L8: Entry 1 of 7 File: USPT Oct 8, 2002

US-PAT-NO: 6463365
DOCUMENT-IDENTIFIER: US 6463365 B1

TITLE: System and method for controlling the attitude of a space craft

DATE-ISSUED: October 8, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Anagnost; John J.	Torrance	CA		
Kiunke; Paul C.	Newbury Park	CA		

US-CL-CURRENT: 701/13; 244/164

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 2. Document ID: US 6347262 B1

L8: Entry 2 of 7 File: USPT Feb 12, 2002

US-PAT-NO: 6347262
DOCUMENT-IDENTIFIER: US 6347262 B1

TITLE: Minimum fuel attitude and nutation controller for spinning spacecraft

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw. De

☐ 3. Document ID: US 6205378 B1

L8: Entry 3 of 7 File: USPT Mar 20, 2001

US-PAT-NO: 6205378
DOCUMENT-IDENTIFIER: US 6205378 B1

TITLE: Adaptive mass expulsion attitude control system

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 4. Document ID: US 5884869 A

L8: Entry 4 of 7 File: USPT Mar 23, 1999

US-PAT-NO: 5884869
DOCUMENT-IDENTIFIER: US 5884869 A

TITLE: Satellite spin vector control with sun sensor

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 5. Document ID: US 5850992 A

L8: Entry 5 of 7 File: USPT Dec 22, 1998

US-PAT-NO: 5850992
DOCUMENT-IDENTIFIER: US 5850992 A
**** See image for Certificate of Correction ****

TITLE: Method for controlling the pitch attitude of a satellite by means of solar radiation pressure

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 6. Document ID: US 5349532 A

L8: Entry 6 of 7 File: USPT Sep 20, 1994

US-PAT-NO: 5349532
DOCUMENT-IDENTIFIER: US 5349532 A

TITLE: Spacecraft attitude control and momentum unloading using gimballed and throttled thrusters

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

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☐ 7. Document ID: US 4837699 A

L8: Entry 7 of 7 File: USPT Jun 6, 1989

US-PAT-NO: 4837699
DOCUMENT-IDENTIFIER: US 4837699 A

TITLE: Method for controlling the spin axis attitude of a spinning spacecraft

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

10/505140 A

L8: Entry 2 of 7 File: USPT Feb 12, 2002

DOCUMENT-IDENTIFIER: US 6347262 B1
TITLE: Minimum fuel attitude and nutation controller for spinning spacecraft

Application Filing Date (1):
20000105

Detailed Description Text (6):
The activation of one of the axial thrusters 120 allows control of the spacecraft 102 attitude error .phi..sub.0 118. However, the timing of such activation is critical to assure that the proper torque is applied to the spacecraft 102. For example, in the illustration presented in FIG. 1B, the attitude error .phi..sub.0 118 and the axial thruster 120A are co-aligned, and a pulse of the axial thruster 120A causes the spacecraft 102 to rotate about second axis A1 to null out the attitude error .phi..sub.0 118.

Detailed Description Text (7):
Spin stabilized spacecraft typically utilize unique spin sensors and control logic to determine the timing, duration, and impulse delivered by the axial thrusters 120 to null out the attitude error angle .phi..sub.0 118 and nutation errors. One such system is disclosed in U.S. Pat. No. 4,837,699, which is hereby incorporated by reference herein. However, as described herein, these sensors are not well suited for use when the spacecraft 102 enters the body-stabilized mode. Hence, such unique spin sensors and control logic add to the cost and complexity of the spacecraft. Although it is possible to use simple continuous spin thruster control, such implementations typically result in unacceptably high propellant consumption, and are thus generally only useful where short duration, high bandwidth control is desired.

Detailed Description Text (8):
Using the present invention, the application of torque is controlled by a spacecraft control processor 114, which utilizes the same instruments used in the body stabilized mode (namely, attitude rate instruments and sensors 110 and attitude position sensors 112) to determine the proper timing, duration, and impulse to be delivered by the axial thrusters 120 to null out the attitude error angle .phi..sub.0 118. This allows a single sensor set and control structure to be used for both spinning and body-stabilized operational modes.

Detailed Description Text (16):
The control compensation G(s) 222 is used to filter out unwanted signal components such as wobble, misalignment, noise, flexible body modes. In addition to, or in the alternative, separate compensation filters can be applied to the angular rate paths and angle feedback paths. Further, it is noted that although the foregoing implementation is described in terms of external torques applied to the spacecraft 102 via external thrusters, the present invention is equally applicable to other torqueing devices such as magnetic or electric thrusters.

Detailed Description Text (45):
The spin axis controller uses the error signal e(t) 228 described above to trigger axial thruster 120 pulses on its positive half cycles to correct the attitude error .PHI..sub.0 down to the control deadband defined by the deadband 226A

element. This provides spin-synchronous attitude correction pulses, which can be properly phased by judicious selection of the location of the sensors 110, 112, torquer, and control compensation G(s) 222. Control compensation G(s) substantially removes constant rate and attitude components due to imbalance, alignment and other factors, and passes nutation and spin frequency components with perhaps some phase compensation. G(s) may also be designed to substantially reject significant body-fixed disturbance torque step functions induced by misalignments. In an embodiment where the spin rate .omega..sub.s =5 rotations per minute and the inertial ratio .sigma..apprxeq.0.49, a rate to position gain weighting of .alpha.=1.5, and a control thruster deadband of about 0.1 degrees, G(s) may be selected as equal to 5s/[(s+0.1)(s+5)].

Current US Original Classification (1):
701/13

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4

L8: Entry 4 of 7 File: USPT Mar 23, 1999

DOCUMENT-IDENTIFIER: US 5884869 A
TITLE: Satellite spin vector control with sun sensor

Application Filing Date (1):
19960318

Detailed Description Text (17):
The sun sensor signal is subject to corruption. The dynamics involved are not limited to rigid body dynamics. The sensor is subject to being misaligned in azimuth and elevation, the angle between its two null planes can be off-nominal, and there are many effects that can produce an apparent variation in sun angle when none, in fact, exists.

Detailed Description Text (44):
In implementing this system, the concept of a thruster pulse should not be restricted to a single continuous pulse from a single thruster at a single point in time. To achieve a desired effect, it may be best that the command to the actuator be a pulse pattern that may fire more than one thruster, and in a pattern spread out in time. Thruster patterns used in the past have included equal, simultaneous pulses from multiple thrusters. An example of this would be a spinning spacecraft having a pair of radial thrusters whose lines of action are parallel but pass on opposite sides of the spin axis. Firing either alone produces an undesired spinup/spindown torque, but firing equal, simultaneous pulses produce precession torque without spin torque.

Detailed Description Text (54):
As noted in the discussion of FIG. 1, if the spin phase separation of the thrust pattern used for the positive and negative pulses is uncertain, then this produces a systematic precession about the sun line. Solutions to this problem include careful surveying of the thruster alignment for determining the appropriate spin phase for thruster pulses; using the same thruster for both positive and negative pulses (using a spin delay of 0.degree. or 180.degree.); and using the "two equal pulses, half a spin phase apart, from a single thruster" pattern when precession is not desired. When using the latter solution, the timing may need to be adjusted for the effect of recent firing on the effective thruster delay.

Detailed Description Text (60):
There are many variables in the nutation/precession control of even a simple rigid body with plus/minus torquing. The body dynamics have six degrees of freedom and depend on the triaxial inertia of the body and the torque vector components of the thrusters. Much can be done to simplify the problem by construction; but, even if the body is spin-symmetric and balanced, with 180.degree. separated, pure transverse torquing thrusters, the ratio of nutation frequency to spin frequency (.sigma.) is a critical parameter.

Current US Cross Reference Classification (3):
701/13

A

L8: Entry 5 of 7 File: USPT Dec 22, 1998

DOCUMENT-IDENTIFIER: US 5850992 A
**** See image for Certificate of Correction ****
TITLE: Method for controlling the pitch attitude of a satellite by means of solar radiation pressure

Application Filing Date (1):
19970107

Brief Summary Text (35):
Another object of the invention is to obtain maximum benefit for attitude control (about the three axes) and orbit control from electrical propulsion (the great advantage of which is a much better specific impulse than chemical propulsion), of a kinetic energy storage system advantageously with no gyroscopic stiffness based on reaction wheels (lighter in weight than inertia wheels which have a non-null angular momentum at all times) and disturbing forces generated by the solar radiation pressure, in order to be able to dispense with any chemical propulsion in the operational phase and to minimize the overall mass of the components of the satellite dedicated to attitude control (about three axes) and orbit control, at moderate cost (manufacture and launch) and with improved overall reliability (because of the eliminated risk of leakage associated with the use of chemical propulsion).

Brief Summary Text (38):
The tilt means include the drive motor and a second motor disposed between the drive motor and the solar generator panel. The second motor is a rotary motor having an axis inclined at a non-null angle a relative to the given direction and the non-null angle is between 2.degree. and 15.degree.. The tilt means include a pivot motor whose axis is transverse to the given direction, which motor provides a range of movement of at most 15.degree. relative to the given direction.

Brief Summary Text (39):
The tilt means include a second pivot motor whose axis is transverse to the given direction and has a non-null inclination to the axis of the first pivot motor.

Brief Summary Text (44):
The attitude control and orbit correction propulsion system is exclusively electrical and has at least a first pair of two electric thrusters disposed substantially symmetrically relative to the plane of the pitch and yaw axes with non-null inclinations relative to the plane of the roll and yaw axes and to the plane of the pitch and yaw axes and inclinations of not more than approximately 20.degree. to the plane of the roll and pitch axes.

Brief Summary Text (47):
The propulsion system includes a second pair of electric thrusters disposed substantially symmetrical to the plane of the pitch and yaw axes with non-null inclinations to the plane of the roll and yaw axes but in the opposite direction to the thrusters of the first pair, non-null inclinations to the plane of the yaw and pitch axes and inclinations of not more than approximately 20.degree. to the plane of the roll and pitch axes.

Brief Summary Text (68):
Our concept of a satellite with no nominal gyroscopic stiffness, totally unsuited to chemical propulsion during orbit control maneuvers, is suited to the slow accumulation of angular momentum during maneuvers and to a slow return towards a virtually null global angular momentum by the action of low external torques (solar sails, magnetic torques).

Detailed Description Text (76):
Although in the foregoing description it has been regarded as particularly beneficial to have no gyroscopic stiffness, it should be understood that the invention is generally applicable to the case of an angular momentum having a continuously non-null component, for example a component along the Y axis (and therefore with an inertia wheel having a continuously non-null angular momentum about the Y axis, as in FIGS. 4 and 5, for example).

Detailed Description Text (85):
A mass balance associated with the four thrusters and their fuel, as compared with that of a conventional system with 12 chemical thrusters, shows a saving of around 800 kg. For a satellite with a launch weight of four tons and a mission life of 15 years, the additional dry mass is 70 kg for the electric thrusters but the fuel saving [(chemical propulsion)-(Xenonpropulsion)] is 900 kg.

Current US Cross Reference Classification (1):
701/13

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A

L8: Entry 6 of 7 File: USPT Sep 20, 1994

DOCUMENT-IDENTIFIER: US 5349532 A
TITLE: Spacecraft attitude control and momentum unloading using gimballed and throttled thrusters

Application Filing Date (1):
19920428

Detailed Description Text (13):
Simultaneous with the above-described thruster control, the spacecraft momentum wheel controller system 810 continues to operate, also producing torques for the stabilization of spacecraft attitude. The wheel controller system 810 produces larger torques than the gimballed and throttled thrusters 221-224, and is used for coarse control of attitude and momentum, while the gimballed and throttled thrusters 221-224 provide finer control. Should a momentum wheel, e.g., 120, saturate, the thruster control system 802 detects such saturation and adjusts the gimbals 116 and throttles 118 to gradually return the wheels 120, 121 to their reference speeds, the control torque from the thrusters 121-124 equalling the rate of change of wheel, e.g., 120, momentum. Thus, the rate of desaturation depends on the magnitude of the moment produced by the thrusters 221-224.

Detailed Description Text (15):
The first step of the flow in FIG. 6 is to sense at 24 the current attitude of the spacecraft 201, as discussed previously in connection with FIG. 1. The wheel controller 802 responds to roll and pitch attitude changes. A check at 26 is then made to see if ground control 119 has commanded the firing of a pair of ion thrusters, e.g., 221, 224 for position maneuvering. If not, conventional non-ion-thrusting attitude control systems 804 maintain spacecraft momentum 28. Specifically, when none of the thrusters 221-224 is firing, other perturbations of the types previously mentioned cause body torques, producing body attitude errors. Errors in roll and pitch attitude are quickly sensed by the conventional earth sensor 101 of the spacecraft 201 and nulled by storage of the gained momentum in the momentum wheel controller 810 of the spacecraft 201. Yaw errors couple into roll errors, which are estimated and slowly reduced by magnetic torquing in momentum desaturation controller 812. Yaw momentum is also slowly reduced by magnetic torquing. Pitch momentum is quickly reduced in the conventional manner by brief chemical thruster 816 firings.

Detailed Description Text (16):
If check 26 reveals that the ion thrusters, e.g., 221, 224, are firing, a number of subsequent steps control spacecraft 201 attitude and momentum. Before detailing those steps, however, it is instructive to consider the result of spacecraft 201 thrusting without these subsequent control steps. Without throttling and gimballing in accordance with the present invention, when one pair of the thrusters 221-224 are firing for north-south stationkeeping, much larger body torques than in the non-thrusting mode result due to misalignment of thrust from the center of mass. As in the non-thrusting mode, the wheel controller 810 attempts to null roll and pitch errors, but the wheels 120, 121 may not be able to store new momentum quickly enough to do so, or they may reach the limits of their operational speeds. Yaw error is uncontrolled, as magnetic torquer correction is far too slow to correct yaw error or unload momentum.

Detailed Description Text (17):
In accordance with the present invention, these effects are avoided by introducing counteracting body torques by throttling and gimballing thrusters 221-224 during firing. Specifically, and referring again to FIG. 6, the state of spacecraft 201 momentum relative to a reference value is measured at 29, the sensed and desired momentum and attitude are compared at 30, and a check 32 is made to see whether the sensed momentum of the spacecraft 201 is equal to the reference value. If so, processing passes to step 36. If not, the torques required to return the spacecraft 201 momentum state to the desired reference value are calculated at 34, and processing passes to step 36. In step 36, another check is made to see whether the sensed yaw attitude of the spacecraft 201 is equal to the desired yaw attitude. If so, processing passes to step 40. Otherwise, the torques required to maneuver the spacecraft 201 to the desired yaw attitude are calculated at 38, and processing passes to step 40. The gimbal 116 geometry and throttle 118 compensation required to produce the torques determined in steps 34 and 38 are calculated in step 40, and the thrusters, e,g., 221, 224 are gimballed and throttled accordingly 42, before processing iterates from step 24. Through this iterative process, the gimbals 116 and throttles 118 return to their quiescent values when the actual momentum and attitude match the desired values. After a station-keeping maneuver is complete, attitude errors and momentum errors are zero, so no magnetic torque or unload desaturation is needed.

Current US Cross Reference Classification (5):
701/13

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4

L8: Entry 7 of 7 File: USPT Jun 6, 1989

DOCUMENT-IDENTIFIER: US 4837699 A
TITLE: Method for controlling the spin axis attitude of a spinning spacecraft

Application Filing Date (1):
19880705

Detailed Description Text (34):
The Error Threshold Firing Mode (ETF) is the simpler of the two operating modes. Attitude corrections are made whenever a ground commandable threshold is exceeded. The threshold logic monitors the two attitude estimates in the sun fixed frame (U, V). When either of these estimates exceeds its threshold (U.sub.o or V.sub.o), a command to null the attitude in that particular direction is executed. For example, when V.gtoreq.V.sub.o, a V correction of -V.sub.o is performed. The thruster impulse is calibrated in orbit so that an integral number of thruster pulses will nominally result in the desired correction, -V.sub.o. This granularity equals the attitude correction resulting from a single thruster pulse and is a ground commandable parameter which is matched to actual thruster performance.

Detailed Description Text (51):
Two ground commanded control modes, Immediate Attitude Trim (IAT) and Quick Roll Estimate and Attitude Trim (QAT), are incorporated to null the spin axis attitude prior to the stationkeeping maneuvers. In IAT mode the SAC processor uses the latest onboard estimates to execute an immediate attitude trim where U.sub.c =U and V.sub.c =V. In QAT mode the SAC initiates a quick roll attitude estimate using the average of 64 chord length measurements, rather than the normal 256 measurements in the ETF or FTF modes, and the sun frame components of the attitude error estimates are computed with Yaw (.psi.) equal to zero. Then, an immediate trim maneuver is executed in the same fashion as in IAT mode. The estimate of bias is not updated until 6 hours after QAT has occurred to eliminate the transient response. Several modes of SAC operation are commandable. In addition, the sidereal time, orbital angle, and state estimates may all be reset by ground command and nearly all the parameters discussed are programmable.

Detailed Description Text (54):
Other bits in the SAC mode command control the selected input to the earth chord processor (ESPE-A or ESPE-B), the default or alternate gain selection for the estimators, the selection of the SAC spin rate to be a ground command constant or the auxiliary rate estimate from the PDC, the pulse width of commanded thruster maneuver (48 or 96 ms), and the selection of axial thruster (96A or 96B) to be used for attitude corrections. Default power-on conditions are: ESPE-A for earth chord processing, default estimator gains, SAC spin rate equal to a constant (30 rpm), and a 96 ms pulse width with a zero thruster selection. Selection of thruster 96A or 96B is not mutually exclusive. If a zero thruster selection is sent, 96A will be used. If both thrusters are selected by ground command, 96B will be used.

Detailed Description Text (62):
The spin axis controller of the present invention is effective in controlling the trim maneuvers which are needed to maintain the spin axis of the spacecraft within

acceptable limits of a preferred position. The spin axis controller accurately detects minor deviations of axis attitude from the orbit normal by measuring the difference between an earth chord observation from a selected earth sensor and a reference value. The resulting measurement information is processed in accordance with the controller algorithm, including transformation of coordinate data to a sun fixed reference system, and is then utilized to control the firing of a selected axial thruster to correct the detected deviation. The timing of the firing of the thruster is selected to correspond with the rotational position and the orbital position of the satellite so that the firing of the selected thruster will act to both correct the spin axis attitude and adjust the orbital plane, if necessary, thereby economizing on the fuel needed to maintain the spacecraft in the proper attitude. To take care of possible contingencies, the spin axis controller is provided with a plurality of modes of operation. For larger precession errors which are in excess of a preset threshold level, the thruster can be commanded to fire in an error threshold firing mode so that the spin axis is drawn back within the threshold range. For more efficient overall fuel usage, the fixed time firing mode serves to restrict firings to occur near the orbital node crossing, such that the velocity impulses imparted by attitude corrections contribute favorably to the orbit inclination, i.e. north-south stationkeeping. Also, for minimizing the spin axis attitude errors prior to stationkeeping maneuvers, the spin axis controller includes two automatic sequences for nulling estimated attitude error: an immediate attitude trim mode in which the controller uses the latest onboard attitude estimate to execute an immediate attitude trim, and a quick roll estimate and attitude trim mode in which a quick roll estimate is utilized, followed by an immediate attitude trim maneuver. Either of the automatic sequences can be executed from either onboard stored command or by direct ground command. These respective modes of operation of the spin axis controller are effective in assuring that the spacecraft can be controlled by the spin axis controller under the various operating conditions which may be encountered.

Current US Original Classification (1):
701/13

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10/505140

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Search Results - Record(s) 1 through 7 of 7 returned.

☐ 1. Document ID: US 6463365 B1

Using default format because multiple data bases are involved.

L8: Entry 1 of 7 File: USPT Oct 8, 2002

US-PAT-NO: 6463365
DOCUMENT-IDENTIFIER: US 6463365 B1

TITLE: System and method for controlling the attitude of a space craft

DATE-ISSUED: October 8, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Anagnost; John J.	Torrance	CA		
Kiunke; Paul C.	Newbury Park	CA		

US-CL-CURRENT: 701/13; 244/164

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 2. Document ID: US 6347262 B1

L8: Entry 2 of 7 File: USPT Feb 12, 2002

US-PAT-NO: 6347262
DOCUMENT-IDENTIFIER: US 6347262 B1

TITLE: Minimum fuel attitude and nutation controller for spinning spacecraft

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

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☐ 3. Document ID: US 6205378 B1

L8: Entry 3 of 7 File: USPT Mar 20, 2001

US-PAT-NO: 6205378
DOCUMENT-IDENTIFIER: US 6205378 B1

TITLE: Adaptive mass expulsion attitude control system

Full	Title	Citation	Front	Review	Classification	Date	Reference			Claims	KWIC	Draw. De

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☐ 4. Document ID: US 5884869 A

L8: Entry 4 of 7 File: USPT Mar 23, 1999

US-PAT-NO: 5884869
DOCUMENT-IDENTIFIER: US 5884869 A

TITLE: Satellite spin vector control with sun sensor

Full	Title	Citation	Front	Review	Classification	Date	Reference			Claims	KWIC	Draw. De

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☐ 5. Document ID: US 5850992 A

L8: Entry 5 of 7 File: USPT Dec 22, 1998

US-PAT-NO: 5850992
DOCUMENT-IDENTIFIER: US 5850992 A
**** See image for Certificate of Correction ****

TITLE: Method for controlling the pitch attitude of a satellite by means of solar radiation pressure

Full	Title	Citation	Front	Review	Classification	Date	Reference			Claims	KWIC	Draw. De

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☐ 6. Document ID: US 5349532 A

L8: Entry 6 of 7 File: USPT Sep 20, 1994

US-PAT-NO: 5349532
DOCUMENT-IDENTIFIER: US 5349532 A

TITLE: Spacecraft attitude control and momentum unloading using gimballed and throttled thrusters

Full	Title	Citation	Front	Review	Classification	Date	Reference			Claims	KWIC	Draw. De

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☐ 7. Document ID: US 4837699 A

L8: Entry 7 of 7 File: USPT Jun 6, 1989

US-PAT-NO: 4837699
DOCUMENT-IDENTIFIER: US 4837699 A

TITLE: Method for controlling the spin axis attitude of a spinning spacecraft

Full	Title	Citation	Front	Review	Classification	Date	Reference			Claims	KWIC	Draw. De

L8: Entry 1 of 7 File: USPT Oct 8, 2002

DOCUMENT-IDENTIFIER: US 6463365 B1
TITLE: System and method for controlling the attitude of a space craft

Application Filing Date (1):
20000201

Detailed Description Text (20):
Due to the fact that the satellite 10 has net zero momentum, the satellite 10 may be oriented to an arbitrary location using internal forces and moments. No thrusters or external moments are required to perform vehicle stabilization. In addition, dynamic balance mechanisms may be implemented to facilitate vehicle stabilization without departing from the scope of the present invention.

Detailed Description Text (28):
In equation (1), it is assumed that the bus 16 is spinning at exactly the same rate as the payload 14, but in the opposite direction. Although, generally the bus 16 spins at an arbitrary rate compared to the spin rate of the payload 14. The bus 16 spins to null the total inertia of the satellite 10.

Current US Original Classification (1):
701/13

L8: Entry 3 of 7 File: USPT Mar 20, 2001

DOCUMENT-IDENTIFIER: US 6205378 B1
TITLE: Adaptive mass expulsion attitude control system

Application Filing Date (1):
19990729

Detailed Description Text (8):
In FIG. 2, each gas pulse 52 exerts a force on the spacecraft over an interval of time producing a force impulse equal to the integral of the product of the force times the time. This imparts an angular momentum to the spacecraft with an angular velocity that directs the spacecraft back towards the bottom edge of the dead band. Subsequent to the thruster pulse, the retarding external torque of the earth's magnetic field slows down the angular velocity of the spacecraft to a value of zero velocity in the vicinity of the bottom edge of the dead band. The retarding torque continues then to alter the direction of the spacecraft drift to bring the spacecraft attitude with increasing angular velocity back towards the top edge of the dead band. Similar comments apply to the graph of FIG. 3, wherein, if desired, the dead band may be divided into four zones, and error measured from the center of the band may be represented in decibels.

Detailed Description Text (10):
In the acquisition phase, when the spacecraft 20 is first placed into orbit, or after a disruption which offsets its attitude, the attitude error exceeds the preset dead band threshold parameter. The procedure begins with generation of the minimum duration pulse at the beginning of a computation simple time. The thruster impulse duration is to increase monotonically for an error signal larger than the dead band limits according to a predetermined analytic function to a level of 100 percent duty cycle when the pulse duration is equal to the simple time. The system of the invention is operative to stabilize the spacecraft to within a few degrees of the reference sensor null in the acquisition phase.

Detailed Description Text (11):
Fine attitude control is established with a fine attitude sensor with of without an independent rate sensor. The star tracker 32 serves as a suitable fine attitude sensor, and may be operated with a sampled data output rate as low as once per second or even lower. The fine attitude control is able to stabilize the spacecraft to within a fraction of a milliradian (a few hundredths of a degree of arc) of attitude of the reference sensor null.

Detailed Description Text (26):
The circuitry of the observer mixer 126 provides logic functions which generate three signals of the control process. The composite position and rate signal constitutes an output signal which is provided to the thruster modulator at 70. An observer estimated attitude position signal, shown at the output of the integrator 154, is used to generate a centering signal, shown at the output of the threshold circuit 168. This provides an operating condition wherein an average attitude of the dead band is placed near null by addition of the centering signal. The gain K1 regulates the time constant of the centering process. A biased estimate is generated by integration of any long term offsets between the input attitude signal and the observer attitude estimate. The gain K3 regulates the time constant of the

bias estimation. The gain K2 establishes the dynamic response balancing the integrated rate in the input attitude. The observer loop effectively filters potential signal noise from the input attitude signal.

Detailed Description Text (27):
The block diagram of FIG. 8 shows details in the construction of the position/rate estimator 134 for use with the star tracker 32 providing fine attitude without need for a separate rate sensing. The sensor signal and a feedback signal are summed at a summer 170 to provide an output signal which is applied to a first signal channel and a feed forward channel. The estimator 134 includes a summer 172 which sums together signals of the first channel, the feed forward channel, and pulse data from the thruster modulator. The pulse data from the thruster modulator augments the estimator acceleration and rate signals. In the feed forward channel the angular rate portion of the sensor signal is multiplied by an estimator rate gain, and in the first channel, the position (attitude) portion of the sensor signal as multiplied by an estimator position gain. Different values of the gain at employed for the rate and for the position signals so that the contributions of these two components of the error are weighted approximately equally. The output signal of the position gain multiplier is summed at summer 174 with the pulse data from the thruster modulator. The output signal of a summer 174 is integrated at 176 to serve as an output signal of the first channel, this output signal being one of the aforementioned inputs to the summer 172. The output signal of the summer 172 is integrated at 178 to provide an estimate of the spacecraft position, this estimate serving also as the feedback signal applied to the summer 170. The output signal of the summer 172 serves as an estimate of the angular rate of the spacecraft.

Detailed Description Text (29):
FIG. 9 presents a graph providing details in the process of modulating the width of the gas pulse provided by the thruster 40. The pulse width is presented on the vertical axis, and is shown as a function of error input signal in the graph. The independent variable, or conditions, upon which the pulse width is based is presented on the horizontal axis. It is noted that the conditions set forth on the horizontal axis include a dead band plus hysteresis, during which condition the minimum pulse width is employed. As may be appreciated from examination of FIG. 2, a minimum pulse width permits operation with a minimum size of dead band because a single pulse at the minimum width is capable of driving the spacecraft attitude across approximately, but less than, the entire dead band, after which the attitude is allowed to drift back to the top edge of the band. In the acquisition phase wherein the attitude may be way beyond the confines of the dead band, it is necessary for the thruster to generate much larger impulses, this being indicated in FIG. 9 by the condition at the right end of the horizontal axis wherein an individual pulse is wide enough to drive the spacecraft attitude through a displacement equal to many dead bands. As a feature of the invention, is noted that optimum control avoids use of extra wide impulses for the condition wherein the attitude may be slightly outside of the confines of dead band. However, the amount of required pulse width increases much more rapidly for large excursions of attitude away from the dead band. This gives rise to the curved graph shown in FIG. 9.

Detailed Description Text (30):
The thrusters are to be operated in a pulse mode at a sample rate nominally about one second, but other rates can be used. The minimum duration pulse is generated when the attitude error signal exceeds the preset dead band threshold parameter. This pulse is generated at the beginning of the computation sample time. The impulse duration increases monotonically for error signal larger than the dead band according to a predetermined analytic function to a level of 100% duty cycle when the pulse duration is equal to the sample time. The minimum pulse is a set parameter, and has the above-noted value of approximately 0.03 seconds corresponding to the minimum realizable impulse that can be expended by the thruster equipment. A mathematical representation of the functional relationship is

disclosed beneath the graph in FIG. 9.

Current US Original Classification (1):
701/13

L1: Entry 1 of 2 File: USPT Dec 11, 2001

US-PAT-NO: 6330483
DOCUMENT-IDENTIFIER: US 6330483 B1

TITLE: Optimal control system

DATE-ISSUED: December 11, 2001

INVENTOR-INFORMATION:

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APPL-NO: 09/306900 [PALM]
DATE FILED: May 7, 1999

INT-CL: [07] G05 B 13/02

US-CL-ISSUED: 700/28; 700/31, 700/44, 700/45, 700/89, 318/561, 318/606
US-CL-CURRENT: 700/28; 318/561, 318/606, 700/31, 700/44, 700/45, 700/89

FIELD-OF-SEARCH: 700/89, 700/28, 700/29, 700/30, 700/31, 700/37, 700/38-39, 700/44, 700/45, 700/47, 700/41-43, 318/561, 318/606-610

PRIOR-ART-DISCLOSED:

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ART-UNIT: 211

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ABSTRACT:

An optimal control system is described having multiple aspects. In one aspect, an arrangement is provided for eliminating integrator windup. This aspect includes forming a control difference signal that is a combination of differenced inputs and then subsequently integrating and limiting the control difference signal to form a control signal that is provided to the plant. In another aspect, an arrangement is provided for eliminating cross-channel coupling. In this aspect, an error signal is formed as the difference between a commanded signal and a regulator sensor signal. In addition, an injection error signal is combined with the error signal. The injection error is of an amount sufficient to ensure that only an attainable command signal is provided to the plant, without significant cross-channel coupling due to saturation of a control effector. In another aspect, an arrangement is provided for improving output mixing of the control signal between available plant effectors. The aspects of eliminating cross-channel coupling and output mixing rely on an optimization algorithm newly described herein and termed the Dailey L1 Optimization Algorithm.

L1: Entry 2 of 2 File: USPT Oct 31, 2000

US-PAT-NO: 6141606
DOCUMENT-IDENTIFIER: US 6141606 A

TITLE: Wheel speed control system for spacecraft with rejection of null space wheel momentum

DATE-ISSUED: October 31, 2000

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APPL-NO: 09/123767 [PALM]
DATE FILED: July 28, 1998

INT-CL: [07] B64 G 1/28, G05 D 1/00

US-CL-ISSUED: 701/13; 701/3, 244/158R, 244/165, 244/166
US-CL-CURRENT: 701/13; 244/165, 244/166, 701/3

FIELD-OF-SEARCH: 244/158R, 244/165, 244/166, 701/13

PRIOR-ART-DISCLOSED:

U.S. PATENT DOCUMENTS

Search Selected Search ALL Clear

	PAT-NO	ISSUE-DATE	PATENTEE-NAME	US-CL
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ART-UNIT: 361

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ABSTRACT:

A spacecraft attitude control system uses at least four reaction wheels In order to minimize reaction wheel speed and therefore power, a wheel speed control means system is provided. The wheel speed control means monitors the wheel speeds and controls wheel speed nullspace components to keep the wheel speeds as small as possible.

20 Claims, 3 Drawing figures

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